Piezoelectric Polymer Leg Muscle for Buglike Explorers

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We propose a design for a piezoelectric leg muscle and its attachment to the leg and body. The muscle will consist of ten "bellows" actuators[1] connected mechanically in series. Its size will be $2.5x2.5x2.5 \text{ cm}^3$ (a 1-inch cube). We have built individual actuators of this size. Each actuator consists of four squares cut from specially electroded 28 micron PVDF sheets from AMP, then bonded together with precurvature into two bimorphs, which are bonded together into the bellows-shaped actuator. We have connected actuators of a larger size ($5x5 \text{ cm}^2$) in mechanical series. We will report at this Workshop on our progress in the intricate task of connecting ten such $2.5x2.5 \text{ cm}^2$ actuators in series mechanically and in parallel electrically. The next step will be connecting the muscles to the body and leg. The eventual goal will be to have a bug with six legs, each leg consisting of an upper and lower part controlled by two muscles. The control of the coordinated leg motion will be a daunting problem.

The individual actuator of bellows shape has dimensions $2.5x2.5x0.25 \text{ cm}^3$ and has 0.27 g mass, so the muscle consisting of ten such actuators should have mass near 3 g. The $5x5 \text{ cm}^2$ actuator, of the type we use on our NASA zero-g antivibration mount project, displaces 1.6 mm with 500 volts applied. We expect 1/4 that much displacement, or 0.4 mm, for the $2.5x2.5 \text{ cm}^2$ individual actuator, or 4 mm for the stack of 10, with 500 volts. The $5x5 \text{ cm}^2$ actuator exerts 0.02 N (2 g weight, or 0.0044 lb) force for no displacement at 500 volts, and this force should be the same for the $2.5x2.5 \text{ cm}^2$ actuator, and for a stack of such actuators. The "authority" of the muscle, which is the work it could do for 500 volts applied, would be 0.5(4 mm)(0.02 N)=0.04 N-mm. The maximum allowable compressive force, which flattens the bellows shape, is 18 g weight, or 0.18 N.

This muscle, when attached as shown, could supply 30^o angular motion of the upper leg relative to the body, or the lower leg relative to the upper leg. Three attractive features of the design are 1), its use of an existing actuator, 2) its light weight, and 3) its lack of bearings or sliding parts, made possible by the flexibility of the actuator stack and the leaf-spring connections of the upper leg to the body and to the lower leg.

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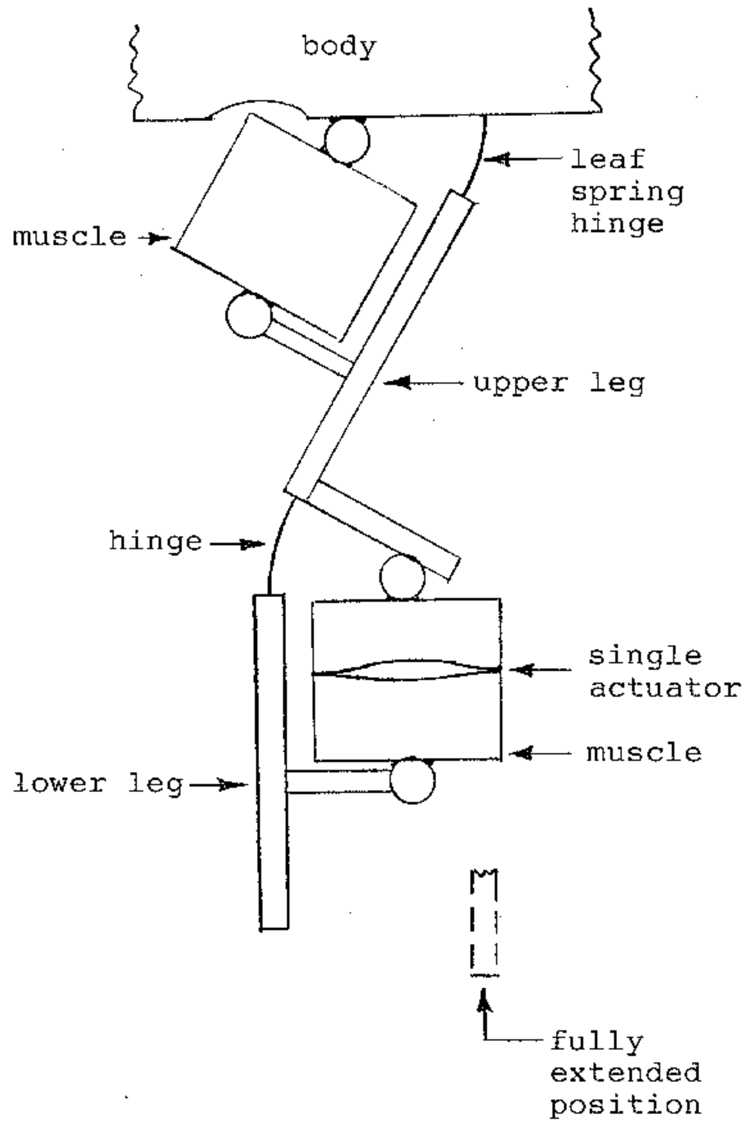
[1]V.H. Schmidt, D. Brandt, F. Holloway, A. Vinogradov, and D. Rosenberg, Proc. 10th IEEE Internat. Symposium on Applications of Ferroelectrics, E. Brunswick, NJ, Aug. 1996, pp. 377-380, IEEE Publ. No. 0-7803-3355-1/96.



Full Size View of Retracted Leg with Piezoelectric Muscles

"PIEZOELECTRIC LEG MUSCLE FOR BIOMORPHIC EXPLORERS"

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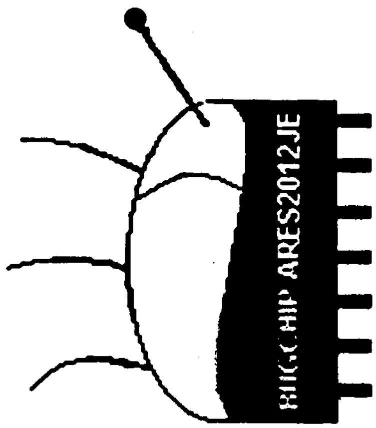
Montana State University - Bozeman

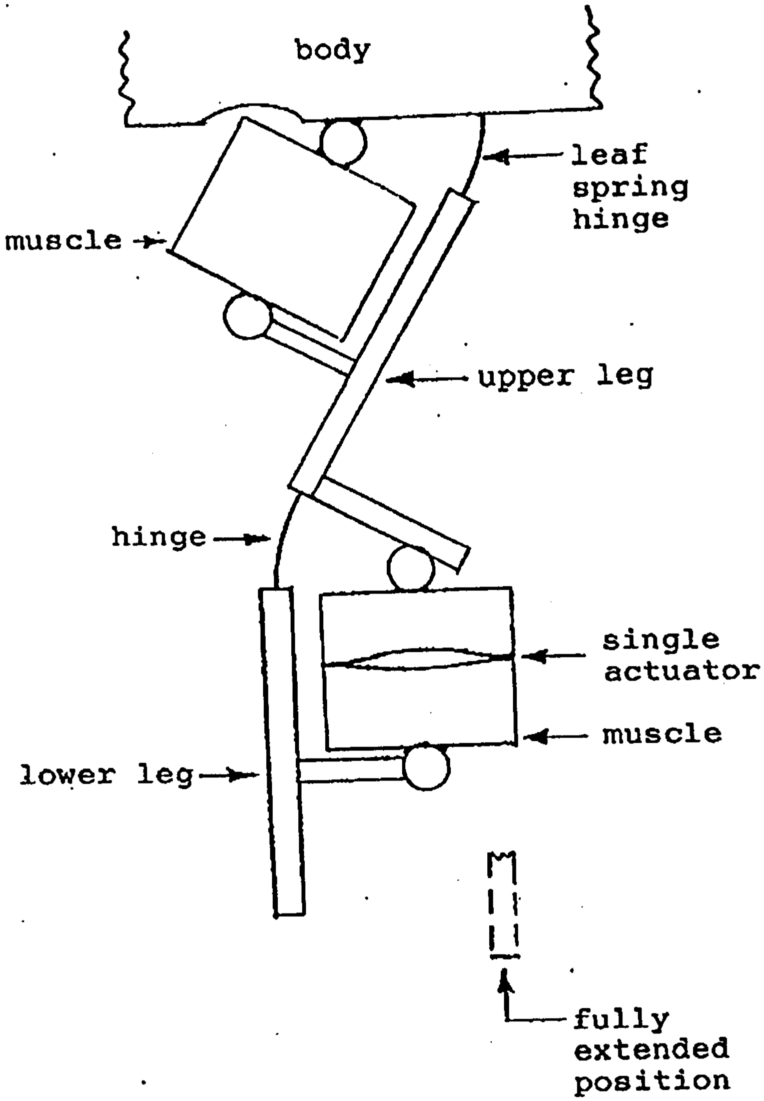
NMP Biomorphic Explorers Workshop
JPL
8/20/98



Part One
Intro
Previous Design
2-Direction Theory(2)
Scale

Part Two
Piezoelectricity
Electrical diagram
Mechanical diagram(2)
Closing

Supported by NASA EPSCoR grant NCCW-0058



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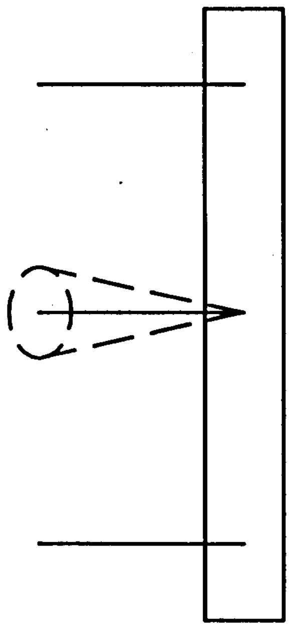
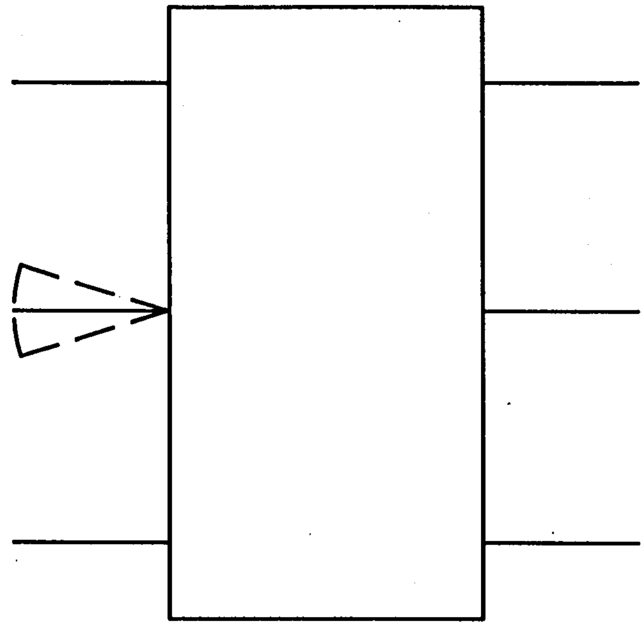
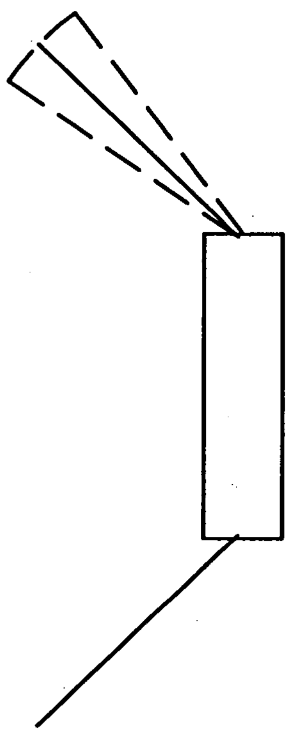
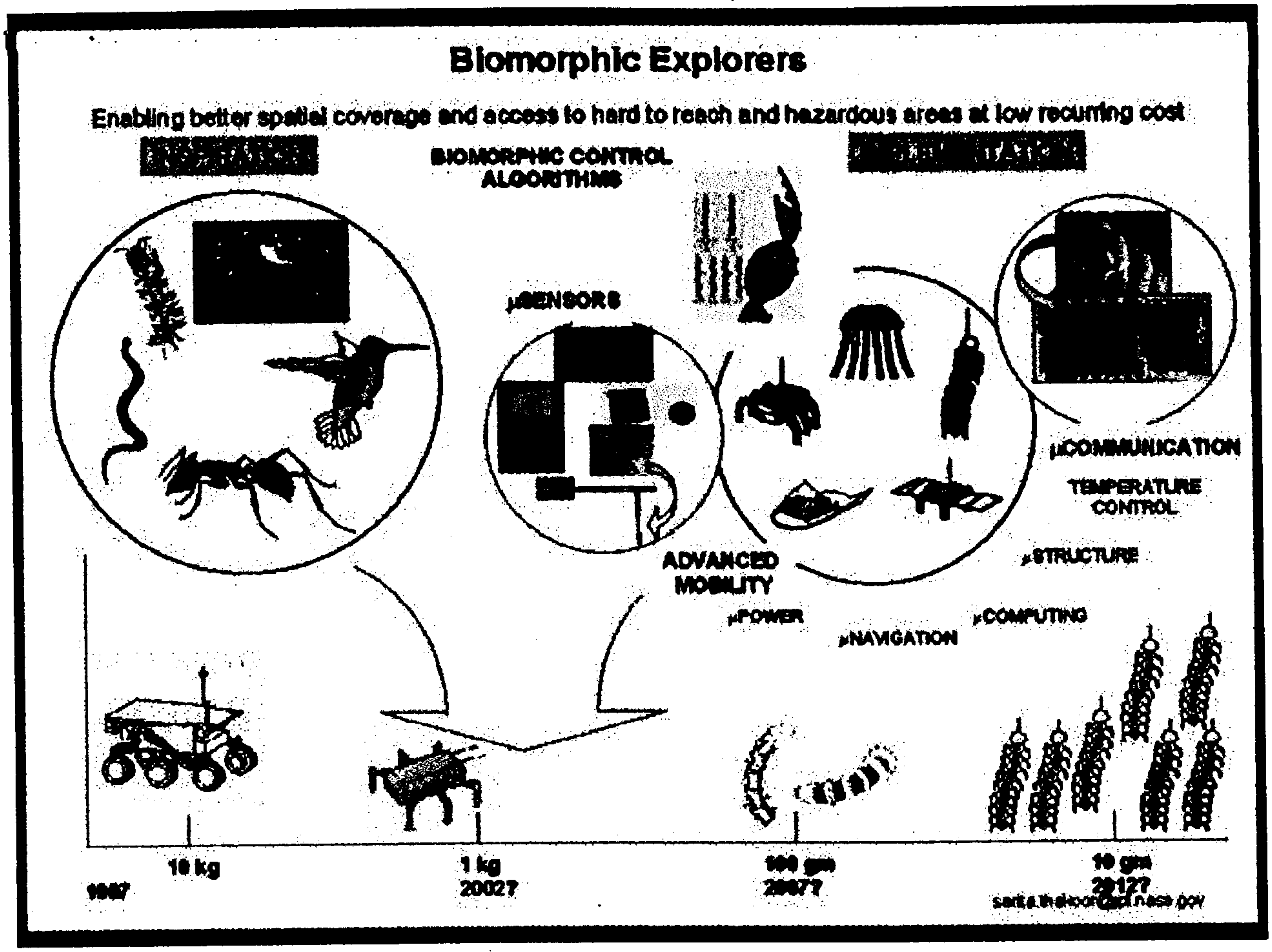
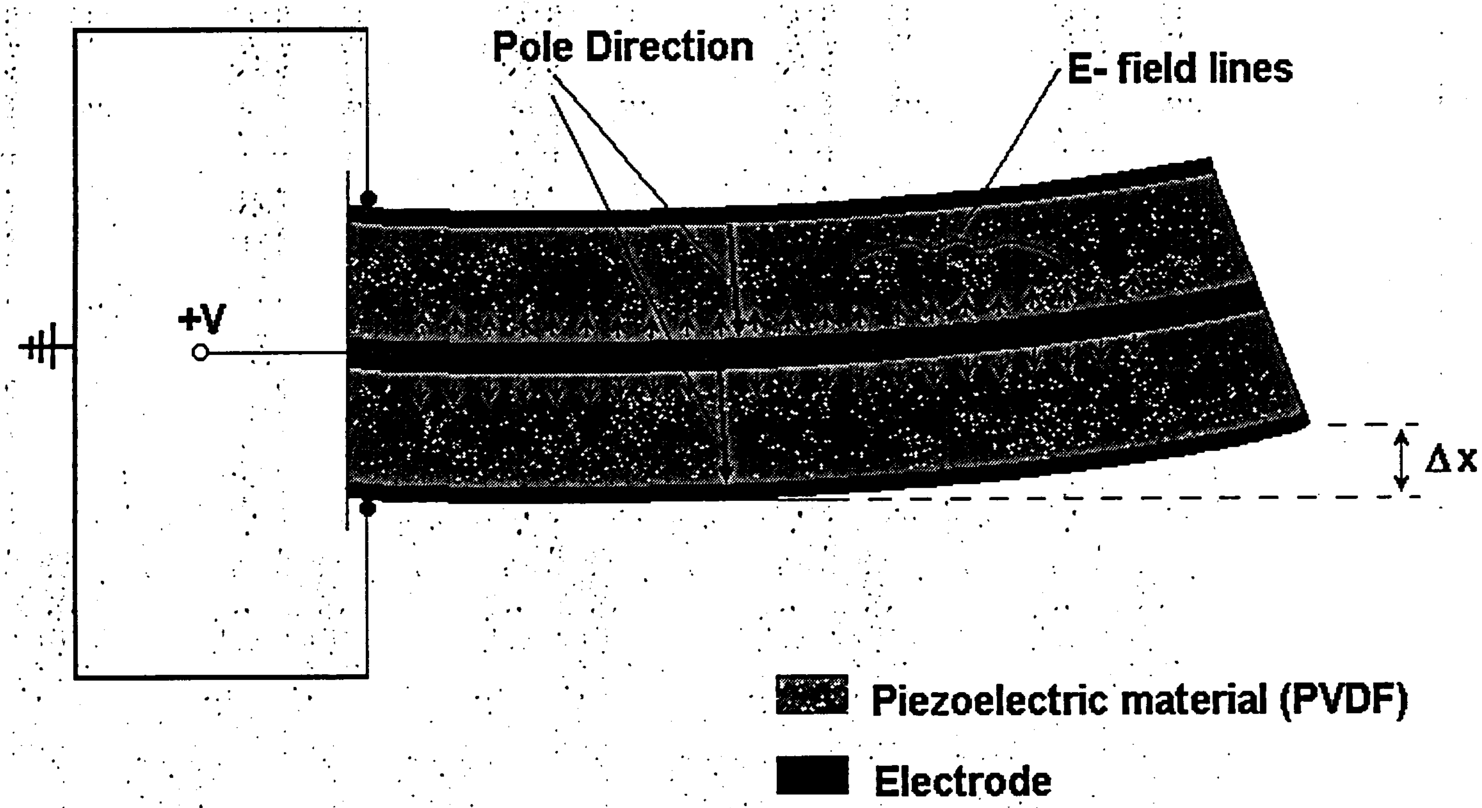




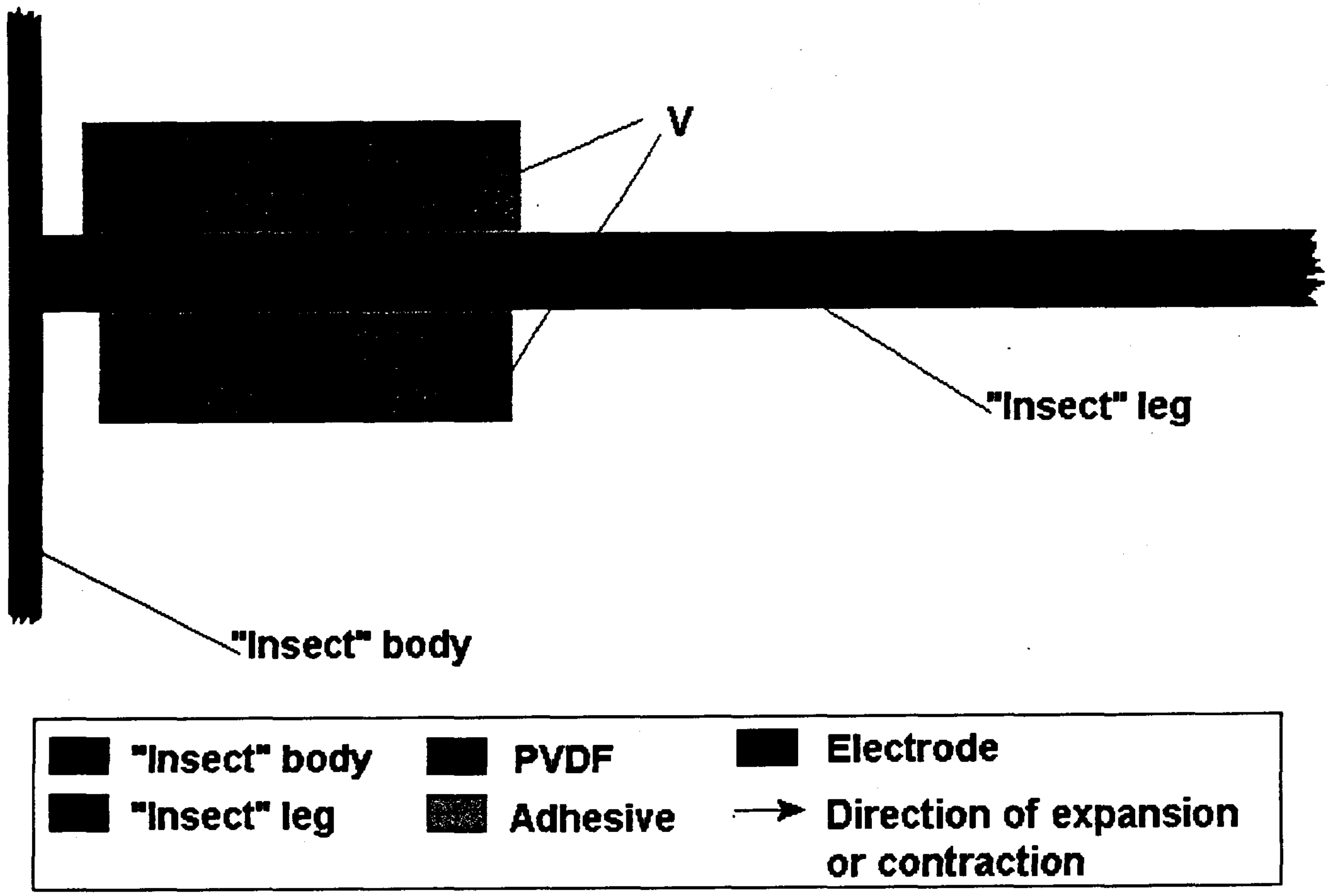



Biomorphic Explorers
Enabling better spatial coverage and access to hard to reach and hazardous areas at low recurring cost
BIOMORPHIC CONTROL ALGORITHMS
μSENSORS
μCOMMUNICATION
TEMPERATURE CONTROL
ADVANCED MOBILITY
μSTRUCTURE
μPOWER
μNAVIGATION
μCOMPUTING
10 kg
1997
1 kg
2002?
100 gm
2007?
10 gm
2012?

Piezoelectricity

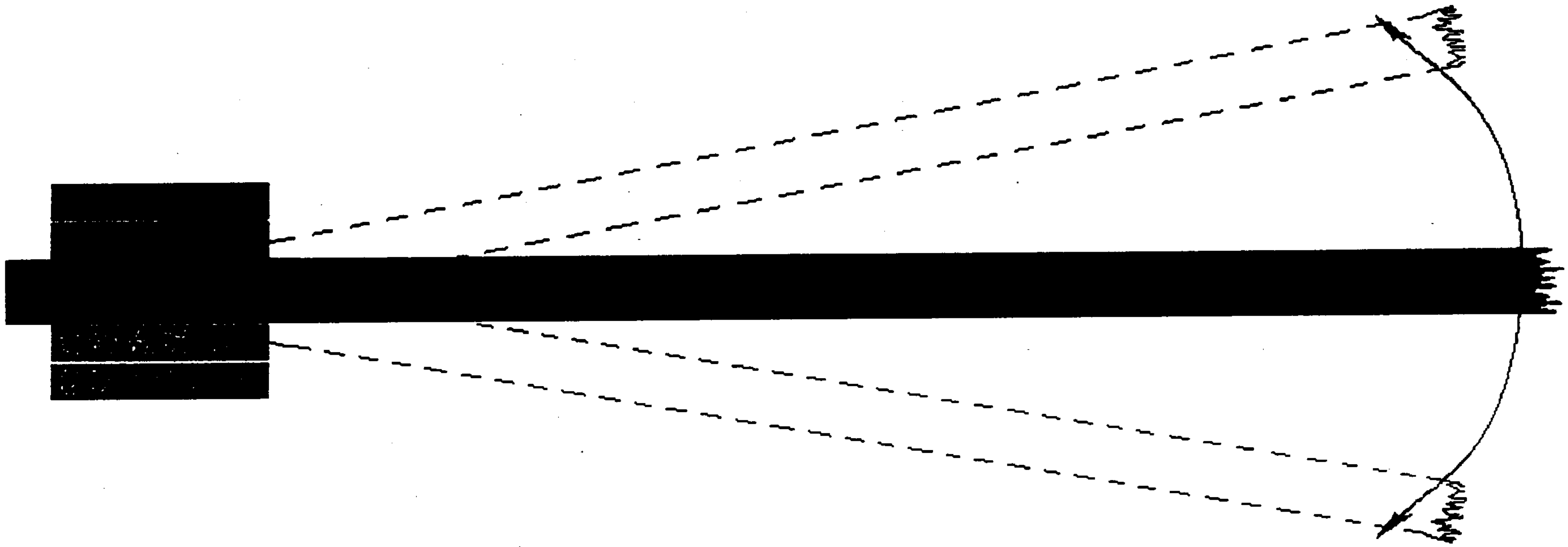


Section of "Insect" Leg with Piezoelectric Muscle



Motion of "Insect" Leg

(view of cross-section)



Full Piezoelectric "Insect" Leg